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5 TITLE OF THE INVENTION

11/2/93 ~~COMPLEX SHAPED ARTICLES AND METHOD OF MANUFACTURE~~

Making Complex Shaped Articles
3/18/99
Linda

10 FIELD OF THE INVENTION

22 4/2/93 This application is a continuation-in-part of co-pending application Serial No. 08/939,238 filed September 29, 1997, ^{now abandoned,} which, in turn, is a continuation of application Serial No. 08/594,856 filed January 31, 1996 now abandoned.

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20 The present invention generally relates to complex shaped articles and a method for manufacturing such articles. Illustrative of such complex shaped articles are aerodynamic airfoils (e.g., wings, rudders, elevators, and the like for use on planes, air ships, space vessels, and the like), hydrodynamic airfoils (e.g., ship rudders, ship stabilizers, sail boat keels, and the like), and other airfoil articles such as aquatic sports boards (e.g., surfboards, sailboards, water skis, and the like).

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a These complex shaped articles have generally followed similar, parallel routes in the evolution of their development and improvement; namely, lighter, more durable articles having complex shapes designed to perform in a selected environment. The development and improvement of such complex shaped articles can be traced through an aquatic sports board such as a surf board which presents a common background for and is exemplary of ~~other the~~ other types of complex shaped articles mentioned above; i.e., aerodynamic air foils and hydrodynamic air foils. The ensuing description of the invention, therefor, should be understood as being only exemplary and illustrative of these other types of complex shaped articles.

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5 Riding a board on the crest of a wave as it approaches the shore dates back
to at least the eighteenth century when European sailors documented the feat in
the Sandwich Islands. The sport spread from Hawaii to California, Australia, South
Africa and around the world in the twentieth century. As the sport was introduced
10 around the world, the surfboards used were heavy, curvilinear artifacts measuring
from twelve to twenty feet in length so that only the strongest surfers could handle
them. With the advent of new technologies, construction techniques, and
materials, the sport has grown in popularity and surfing enthusiasts have placed
increasing demands on performance, maneuverability, speed, durability, weight and
size.

15 Typical, commercially available surfboards are constructed from a core of
foam or honeycomb material which is encased in a protective layer of reinforced
resin and which usually include fins on their bottom surface to impart stability and
control. These surfboards generally have curved profiles which aid a rider in
20 maintaining fore and aft as well as side to side balance and which approximates the
curvature of the forward slope of a wave. In efforts to improve their performance,
aquatic sports boards have been produced having a variety of configurations and
shapes. Fins have been added to provide stability and further improve performance
and different types of materials have been used for their fabrication. Manufacturing
25 techniques for such aquatic sports boards have generally required the use of
complex molds, processes and tooling.

30 Surfboard riders generally desire a surfboard that will readily enable the user
to attain maximum maneuverability within a wide range of speeds and to achieve
the maximum speed possible for best overall performance. Maneuverability is
governed primarily by the shape and the weight distribution of the surfboard which
is typically augmented by the addition of one or more specially shaped fins on its

underside. Weight is an important consideration in achieving maneuverability as minimum weight is a key factor in achieving the maximum speed possible for a specific surfboard design. Durability, resistance to damage, structural integrity, long term usability and appearance are other important requirements for the user and depend upon construction materials, manufacturing techniques and construction and structural design.

The development of and improvements to surfboards have been directed toward their construction, shape, maneuverability, speed, and decreased weight, but the combination of high performance, minimum weight, durability and attractive appearance have been difficult to obtain or have been unattainable. A simple method for their manufacture has been equally elusive.

Many attempts have been made to decrease the weight and improve the performance, construction and durability of aquatic sports boards. The literature for aquatic sports boards have described the use of honeycomb material, foam and other similar materials for their construction. Attempts to manufacture such aquatic sports boards have generally required the use of complex and costly molds, processes and tooling. Consequently, there still remains a need for light weight, high strength aquatic sports boards that will have long term durability, a high degree of maneuverability, an attractive appearance and that are easy and inexpensive to manufacture and that do not require complex molds, processes or tooling for their manufacture.

Surfboards having foam cores have been attempted. For example, US Patent 3,160,987 to Kelly, Jr. discloses a hydroplane surfboard fabricated from a fiberglass covered, air expanded plastic foam or balsam wood. The surfboard has a planing surface and a scorpion tail so that a rider, by body movement or shift in

5 weight, can bring the planing surface into partial or full play or induce drag thereby achieving a wide range of speeds while maintaining maneuverability during surfing.

10 US Patent 4,713,032 and its divisional US Patent 4,806,302 both to Frank disclosed a method for manufacturing surfboards and sail boards in which a prefabricated foam core has fibrous material wound about it. A resin such as polyurethane is especially set with a reaction retarder and poured onto the fibrous material whereupon the foam core is then inserted into a molding tool and the mold is closed to cure the resin.

15 US Patent 3,543,315 to Hoffman discloses a soft board fabrication in which a surfboard with a low density core is provided with a skin of depressible material. The core can be constructed from a phenolic impregnated paper honeycomb material.

20 US Patent 5,145,430 to Keys, et.al. discloses a surf craft such as a surfboard or windsurfer having a planing plank with a stiffening spine integral with the planing plank to impart additional strength and flexibility. The surf craft has a sandwich construction with a core of foam material encased by a shell of fiber reinforced resin.

25 Hollow surfboards and sail boards have also been attempted. For example, US Patent 3,514,798 to Ellis discloses a surfboard with an outer shell or skin of solidified laminating polyester resin adhered to a sheet of honeycomb material and a longitudinal cavity within the surfboard. A sheet of glass cloth is pressed onto the outer shell or skin of solidified laminating polyester resin while the resin is still moist and it is then impregnated with the same resin while in a mold. The mold consists of two halves having the configuration of the surfboard when the mold is closed.

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5 The moist outer shell is pressed onto the honeycomb material which is then impregnated with a thermosetting phenolic resin and secured by adhesion. The resulting structure includes considerable air space within the body of the surfboard.

10 US Patent 4,964,825 to Paccoret discloses an aquatic board construction for surfboards and sail boards in which shaped upper and lower sections are joined together to form a board with a generally hollow interior. Each section is formed with a generally sandwich construction including a high strength outer skin, an inner skin spaced from the outer skin, and a core formed from filler material which is sandwiched between the inner and outer skins. The inner and outer skins can be
15 formed from one or more layers of a cured thermosetting resin which has been impregnated into a fabric material. The core can be provided from a foam or honeycomb material.

20 US Patent 5,266,249 to Grimes III, et.al. discloses a method of forming a hollow, fiber reinforced plastic structure, such as the hull of a sail board, from a fiber reinforced plastic material in a female mold.

Foam filled honeycomb and foam filled plastic objects are also of interest.

25 For example, US Patent 4,797,312 to Sherwood discloses a foam-honeycomb article and method for its manufacture wherein expanded foam in the cells of a multi-cell honeycomb material braces the honeycomb side walls against collapse to increase the strength and rigidity of the article.

30 US Patent 4,383,955 to Rubio discloses a process for fabricating hollow, foam filled, reinforced plastic objects such as surfboards using a multi-part mold.

5 US Patent 4,510,105 to Sherwood discloses a method for molding an article having a core of foam and a surface reinforced by fiberglass clothe which can be used as a surfboard.

10 Foam filled honeycomb core skis and honeycomb core skis have been disclosed.

For example, US Patent 3,276, 784 to Anderson discloses a laminated snow ski having a foam filled honeycomb core. The ski construction is composed of a
15 molded, elongated, resin impregnated fiberglass outer shell and a foam filled aluminum honeycomb core integrally bonded to the interior surfaces of the fiberglass outer shell.

US Patent 3,734,519 to Bennett discloses a one shot molded ski having cored recesses at right angles to the general plane of the ski.

US Patent 3,201,138 to Brown, Jr. discloses a laminated ski construction with a cellular honeycomb core.

US Patent 5,183,618 to Pascal, et.al. discloses a process for manufacturing
25 a ski whose body includes a core covered with a shell and which is fabricated in a mold cavity. The core can include a synthetic foam or aluminum honeycomb.

As can be seen from the foregoing, efforts have been made towards
30 construction, shape, maneuverability, increased speed and decreased weight. However, the combination of high performance, minimum weight, durability and attractive appearance have been difficult to achieve or unattainable, especially for

5 aquatic sports boards. Attempts to manufacture such aquatic sports boards have
generally required complex molds, processes and tooling. Honeycomb core
shaping, for example, is typically performed on a five axis milling machine in order
to obtain the complex shapes necessary for contouring aquatic sports boards.
Such milling machines normally remove material measuring approximately 2.0" by
10 0.40" at a rate of about 300 linear inches of material per minute consuming about
one hour to shape one side of a typical aquatic sports board. Most of the known
aquatic sports boards are too heavy to achieve the highest speeds and optimum
performance possible while retaining long term durability and an attractive
appearance. A typical "light weight" aquatic sports board currently available
15 weighs about 5.4 pounds.

20 For the foregoing reasons, it would be desirable to provide an aquatic sports
board that is lighter in weight, has high strength, provides long term durability, has
a high degree of maneuverability and an attractive appearance, is easy and
inexpensive to manufacture, and which does not require complex molds, processes,
or costly tooling for its manufacture.

25 As mentioned earlier, the foregoing discussion relating to aquatic sports
boards and their manufacture is equally applicable to the other types of complex
shaped articles described hereinabove; i.e., aerodynamic air foils, hydrodynamic air
foils and other air foil articles.

30 SUMMARY OF THE INVENTION

The present invention is directed to complex shaped articles and a method
for manufacturing light weight, high strength complex shaped articles having long

5 term durability and a high degree of maneuverability that is simple, easy and inexpensive, does not require complex molds, processes or tooling, and that will result in a significant reduction in weight of such complex shaped articles.

10 Features of the invention include a one piece honeycomb core conformably shaped for dynamic movement, formed edges, and an outer skin having at least one layer of fiber reinforced resin adjoined to the honeycomb core for protecting and encasing the honeycomb core and to provide a drag resistant surface.

15 In general, the method for manufacturing the complex shaped articles of the invention comprises: trimming, cutting and shaping a core to a desired size and shape; deforming said core; permanently setting the shape and contour of said core; affixing edges to said core; and, affixing at least one layer of fiber reinforced resin to the top and bottom surfaces of said core.

20 Illustrative and exemplary of the complex shaped articles that can be provided according to the present invention are:

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- An article having a contoured arc extending along its longitudinal axis from the front end to the rear end of said article and a contoured arc extending across its transverse axis between the opposed sides of said article such that a concave, symmetrical contour is defined on the upper surface of said article and a convex, symmetrical contour is defined on the lower surface of said article.

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Articles having this type of complex shape can be used for aquatic sports boards such as surfboards and sail boards. When grooves are added to their bottom, contact surfaces and their forward ends are turned upwardly, such articles can be used as snow skis, water skis, hydroplanes, and the like.

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- An article having a contoured, arcuate shape on one surface thereof extending across its transverse axis between the opposed sides of said article and extending along its longitudinal axis from one end to the other of said article such that a convex, symmetrical arc is defined between said opposed sides on one surface of said article, said convex arc being significantly higher at one of said opposed sides and tapering therefrom across said transverse axis and along said longitudinal axis to a significantly lower height at the other of said opposed sides.

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Articles having this type of complex shape can be used as aerodynamic air foils such as wings and elevators for air planes, air ships, space vessels, and the like, as well as hydrodynamic air foils such as stabilizers for ships.

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- Articles having a symmetrical, contoured arcuate shape on both planar surfaces of said article extending across the transverse axis of each planar surface between the opposed sides of said article and extending along the longitudinal axis from one end to the other on each planar surface of said article such that a symmetrical, convex arc is defined between said opposed sides along said longitudinal axis on each of said planar surfaces, said convex arc being significantly higher at one of said opposed sides on

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5 each of said planar surfaces and tapering therefrom across said transverse axis of each of said planar surfaces and along said longitudinal axis to a significantly lower height at the other of said opposed sides.

10 Articles having this type of complex shape can be used as aerodynamic air foils such as wings, rudders and elevators of air planes, air ships, space vessels, and the like, as well as hydrodynamic air foils such as rudders, stabilizers, keels, and the like for ships and sailing vessels.

15 BRIEF DESCRIPTION OF THE DRAWING

20 The features, aspects and advantages of the present invention will become more apparent from the ensuing description when considered together with the accompanying drawing which illustrates the complex shaped articles of the invention through its application to an aquatic sports board and in which:

Fig. 1 is a perspective view of an aquatic sports board constructed in accordance with the present invention;

25 Fig. 2 is an inverted perspective view of the aft portion of the aquatic sports board shown in Fig. 1 showing a cross section at the mid section of the aquatic sports board;

30 Fig. 3 is a perspective view of a flat sheet of semi-rigid, honeycomb core material prior to being trimmed;

Fig. 4 is a perspective view of the semi-rigid, honeycomb core material

5 shown in Fig. 3 after it has been trimmed to shape;

Fig. 5 is a perspective view of the trimmed and shaped semi-rigid, honeycomb core material of Fig. 4 shown abutted against a fixture in preparation for cutting;

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Fig. 6 is an end view of the trimmed and shaped semi-rigid, honeycomb core material of Fig. 5 being cut by a horizontal band saw as it is retained abutted against the fixture;

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Fig. 7 is a perspective view of the semi-rigid, honeycomb core material after having been cut to size and removed from the fixture shown with its edges chamfered and readied to accept edge molds;

Fig. 8 is a perspective view of an edge mold that can be used to conform a desired shape and curvature to one of the edges of the aquatic sports board;

Fig. 9 is a side view of a semi-rigid, honeycomb core that can be used in the present invention after the honeycomb core material has been heated and formed to retain a desired conformally bent contoured shape;

Fig. 10 is a top view of a sheet of honeycomb core material with a mixture of epoxy resin, polyamide and phenolic hollow spheres poured into the cells of the honeycomb sheet in an area pattern that defines a desired fin shape; and,

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Fig. 11 is a side view of an optional fin bonded to a flat glass laminate which can then be mounted to the bottom surface of an aquatic sports board constructed

5 in accordance with the present invention.

DETAILED DESCRIPTION OF THE DRAWING AND THE INVENTION

10 With reference to the drawing wherein like reference numerals identify like parts Figs. 1 and 2 illustrate as an embodiment of the invention an aquatic sports board 10 for use in water sports having a top surface 12, a bottom surface 14 and opposed side edges 16. Optionally, a fin 18 can be secured to the bottom surface 14 to provide stability and maneuverability. The top surface 12, bottom surface 14 and opposed side edges 16 can each be provided with at least one layer of a fiber reinforced resin to form a top skin 20, a bottom skin 22 and formed edges 24 on the opposed side edges 16 bonded to a core of honeycomb material 26 to comprised the aquatic sports board 10. The fiber reinforced resin serves to encase and protect the honeycomb core 26 and also provides a drag resistant surface for water borne (i.e., hydrodynamic) movement of the aquatic sports board 10.

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Sub E17 Any suitable, commercially available fiber reinforced resin can be used for this purpose such as glass or Kevlar fiber reinforced resin. [The honeycomb core 26 which is conformably shaped for water borne dynamic movement of the aquatic sports board 10, can also be provided from commercially available, semi-rigid, thermosetting honeycomb materials such as Nomex honeycomb, a honeycomb paper product available from the Kraft Paper Company under the trade name , or other appropriate honeycomb material that can be deformed and contoured to a predetermined, fixed shape.]

30 Portions of the top surface 12, bottom surface 14 and opposed side edges 16 of the aquatic sports board 10 can be finished with a durable coating such as an

5 epoxy paint or other suitable material, or can be left unfinished to provide a view of the honeycomb core material 26 through the semi-transparent top and bottom skins 20 and 22, respectively.

10 *sub* With particular reference to Figs. 3-11 and occasional reference to Figs. 1 and 2, the method of the present *inventive method* generally comprises:

- a) trimming, cutting and shaping a honeycomb core material to a desired size and shape;
- 15 b) deforming the honeycomb core to a desired shape and contour;
- c) permanently setting the shape and contour of the deformed honeycomb core;
- 20 d) affixing edges to the opposed sides of the shaped and contoured honeycomb core; and,
- 25 e) bonding at least one layer of a fiber reinforced resin to the top and bottom surfaces of the honeycomb core.

As shown in Figs. 3-11, a flat sheet of a semi-rigid, honeycomb core material 50 is trimmed to a desired edge shape 52 resulting in an edge shaped honeycomb core 54 (Figs. 3 and 4). The trimmed and edge shaped honeycomb core 54 is then
30 abutted against a fixture or open mold 56 having a predetermined or desired shape and contour such as by placing weights on the top surface 12 of the edge shaped honeycomb core 54 so that the edge shaped honeycomb core 54 conformably

5 adapts to the shape and contour of the fixture or open mold 56 at the interface 58
formed between the bottom surface 14 of the edge shaped honeycomb core 54
and the upper surface of the fixture or open mold 56. Sufficient weight is thus
applied to the top surface 12 of the edge shaped honeycomb core 54 to result in
obtaining a contoured shaped honeycomb core 60 that conformally matches the
10 shape and contour of the fixture or open mold 56 (Fig. 5). The trimmed and edge
shaped honeycomb core 54 can also be abutted against the fixture or open mold 56
by strapping or clamping the edge shaped honeycomb core 54 to the fixture or
open mold 56 or by any other appropriate means to form the desired contoured
shaped honeycomb core 60 that conformally matches the contoured shape of the
15 fixture or open mold 56.

As is shown in Fig. 6, the fixture or open mold 56 and the abutted,
contoured shaped honeycomb core 60 are placed on a table 62 or other suitable
support surface. A horizontal band saw 64 or other appropriate cutting tool is then
20 set at a predetermined distance from the table 62 in order to cut the contoured
shaped honeycomb core 60 to a predetermined, desired distance on a plane parallel
to the longitudinal axis of the contoured shaped honeycomb core 60. Excess
honeycomb core material can be discarded or can be salvaged for use in smaller
parts, the contoured shaped honeycomb core is removed from the fixture or open
25 mold 56, and the shaped opposed edges 52 of the contoured shaped honeycomb
core 60 are prepared by sanding or other appropriate means to form chamfered
shaped ^{opposed} edges 66 to accept edge molds 68. If desired, the contoured
shaped honeycomb core 60 can be inverted, placed on the table 62, and cut
horizontally on its reverse side (i.e., its bottom surface 14) either prior to or after
30 preparing the shaped, opposed edges 52. In most applications for producing
aquatic sports boards 10 having a desired contour

5 and shape, however, this will not be necessary although it may be required or
desired for producing other complex shaped articles of the invention.

10 Each of the edge molds 68 are fabricated to have a concave interior portion
70 that conforms to the desired shape and curvature of the opposed edges 16 of
the aquatic sports board 10. The edge molds 68 are secured to the opposed,
chamfered edges 66 of the contoured shaped honeycomb core 60 in order to
conformally bend the contoured shaped honeycomb core 60 along its longitudinal
axis (and, when desired or required, across its transverse axis) until the
predetermined and desired shape is achieved for the aquatic sports board 10.

15 As mentioned earlier, the contoured shaped honeycomb core can be provided
from a semi-rigid, thermosetting honeycomb core material such as Nomax.
However, the honeycomb core material can also be provided from other appropriate
materials which do not require heat to permanently set them in a predetermined or
desired contoured shaped honeycomb core 60. Illustrative of the honeycomb core
materials that can be used which do not require heat to permanently be set are
such materials as Kraft paper having a honeycomb core, resins that set at room
temperature, and the like. When such materials are not used, heat is applied in
order to form the contoured shaped honeycomb core 60 so as to ensure that the
contoured shaped honeycomb core 60 will retain its desired shape and curvature.
Heat can be applied by using a heat gun or any other suitable means.
After the shape and curvature of the contoured shape honeycomb core 60 has been
set, the edge molds 68 are removed from the chamfered edges 66 of the
honeycomb core 26.

30 A mixture of epoxy resin, polyamide and phenolic or glass hollow spheres is
then prepared in the form of a very light weight, high strength, putty-like substance

5 that can be spread and molded and which will dry or cure to a very hard substance.
The edge molds 68 are then coated with this mixture which acts as an edge fill
after hardening or curing. The edge molds 68 are ^{then} ~~the~~ placed back onto the
chamfered edges 66 of the honeycomb core 26 and the mixture is allowed to
harden or cure after which the edge molds 68 are removed. The hardened or cure
10 edge fill is then filed, sanded, or otherwise shaped to provide the formed opposed
side edges 24 of the aquatic sports board 10.

15 Alternatively, the formed edges 24 of the aquatic sports board can comprise
a polyester mat and a mixture of epoxy resin, polyamide and phenolic or glass
hollow spheres for the edge fill. The polyester mat is first placed in the edge molds
68, then coated with the mixture and allowed to harden and cure. The resultant,
hardened and cured polyester mat surrounded by the hardened and cured edge fill
mixture is then bonded to the honeycomb core 26 using more of the edge fill
mixture which is then allowed to harden and cure. The hardened and cured
20 polyester mat surrounded by the edge fill mixture bonded to the honeycomb core
26 can the be filed, sanded and shaped to provide the formed edges 24 of the
aquatic sports board 10.

25 At least one layer, preferably two layers, of glass or Kevlar reinforced resin is
applied to the top and bottom surfaces 12 and 14, respectively, of the honeycomb
core 26 with an epoxy resin, one surface at a time, to provide the aquatic sports
board outer top skin 20 and bottom skin 22.

30 Optionally, a fin 18 can be secured to the bottom surface 14 of the aquatic
sports board 10 to provide stability and maneuverability. As shown in Fig 10, a
mixture of epoxy resin, polyamide and phenolic or glass hollow spheres can be
poured into the cells of the honeycomb sheet 70 in a pattern area 72 having a

5 desired fin shape 74. An area 76 of the honeycomb sheet 70 internal to the
pattern area 72 is preferably left void of the mixture to provide a lighter weight fin
18. The mixture is allowed to cure and harden after which the honeycomb sheet
70 is laminated between at least one layer of epoxy coated glass or Kevlar fiber
10 reinforced resin on each side of the honeycomb sheet 70. After the epoxy coated
glass or Kevlar fiber reinforced sheet has cured and hardened, the laminated
honeycomb sheet 70 can then be trimmed to the desired fin shape 74 to provide a
trimmed fin 78 (Fig. 11). The edges 80 of the trimmed fin 78 are then filled with a
mixture of epoxy resin, polyamide and phenolic or glass hollow spheres which is
then permitted to cure and harden. The hardened and cured edge fill can then be
15 ground and shaped with a grinder or router or other appropriate tool to obtain the
desired shape of the fin 18.

20 Alternatively, fin 18 can be stamped to the desired shape. After being
stamped, fin 18 can then be coated with at least one additional layer of epoxy
coated glass or Kevlar fiber reinforced resin for added strength and allowed to cure
and dry. Fin 18 can be bonded at fin base 82 to a flat glass laminate 84 for
subsequent mounting to the bottom surface 14 of an aquatic sports board 10 or fin
18 can be bonded directly to the bottom surface 14 of an aquatic sports board 10.
The flat glass laminate 84 can also be bonded directly to the bottom surface 14 of
25 an aquatic sports board or be bolted thereto or otherwise directly affixed using
appropriate hardware.

30 The method of the present invention results in producing an aquatic sports
board 10 that is much lighter in weight, stronger and more durable and damage
resistant than other aquatic sports boards. An aquatic sports board produced
according to the method of the invention is approximately 70 to 75% of the weight
of currently available "light weight" aquatic sports boards. Typically, the average

